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NOTES ON THE NORTH AMERICAN SPECIES OF BRANCHINECTA AND THEIR HABITATS.

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STUDIES FROM THE ZOÖLOGICAL LABORATORY, THE UNIVERSITY OF NEBRASKA,
UNDER THE DIRECTION OF HENRY B. WARD, No. 62.

Three species of *Branchinecta* have been recorded for North America: *B. paludosa* (Müller) Verrill has been reported from Labrador and Greenland. This is an arctic species and is found also in northern Europe and in Siberia. *B. coloradensis* Packard and *B. Lindahli* Packard have been found in the United States.

Of the last two species *B. coloradensis* is the better known. It has been found in Colorado, where it occurs in great numbers, and is recorded for several different localities, all of which, however, are near the center of the state. The original collections were made "near Twin Lakes Creek" south of Leadville, at an elevation of about 3,800 m. (Packard, 1874: 621). Later it was taken near Gray's Peak not far from Georgetown at an altitude of about 3,658 m. and at Weston's Pass southeast of Leadville at an elevation of 3,557 m. (Packard, 1883: 339). After an interval of 21 years it has been recorded recently from Dead Lake in the Pike's Peak region at an elevation of 3,340 m. (Ward, 1904: 139).

B. Lindahli was collected first in a pool at Wallace, Kansas, by Professor Joshua Lindahl, and described and named by Packard (1874: 339-340). Since then, Lafler and Pearse (1898) reported "five or six" specimens from De Witt, Nebraska, and Beardsley (1902: 43) records "one female with eggs" from a temporary pool near Greeley, Colorado. Accordingly this species occurs at a much lower elevation than *B. coloradensis*.

During the summer of 1904 the writer collected 122 adults and many larvæ of *B. coloradensis* from Dead Lake, in the Pike's Peak region. Nine specimens were taken from the same Lake on August 12, 1903.

On October 23, 1904, Professor Aven Nelson collected 16 specimens of *B. Lindahli* at Laramie Hills near Laramie, Wyoming, at an

elevation of 2,317 m. These specimens were found "in an eroded limestone bowl in a canyon always dry except after showers. The bowl will hold a half dozen tubs of water and is rarely entirely dry." This collection was sent to Doctor Ward and was identified by the writer. It contained 10 males and 6 females. This record greatly extends not only the known geographical distribution of this species, but also its vertical distribution. It now belongs with *B. coloradensis* and *B. paludosa* to the short list (Zschokke, 1900: 188) of Phyllopods already recorded in alpine

Species.	<i>B. coloradensis.</i>					<i>B. Lindahli.</i>					<i>B. paludosa.</i>		
	Number of Specimens Measured.	Average.	Maximum.	Minimum.	Measurements by Packard.	Number of Specimens Measured.	Average.	Maximum.	Minimum.	Measurements by Packard.	<i>B. arctica</i> Verrill. ¹	<i>B. gronlandica</i> Verrill. ¹	Measurements by Packard.
Length of male.....	40	19.6	23	16	18	10	13.6	17.5	11.2	8	20	17	15-19 ²
Length of female.....	45	18.3	20.5	16	17	6	12.8	15.5	10	15	20		12-18
Second antenna of male	40	5.33	9	3.5	7	10	3.87	5	2.26	3			4- 5
First division of second antenna.....	40	3.344	6	2.1	4	10	2.23	2.92	1.29	1.5	1.66	2.87	2.5-3
Second division of second antenna	40	1.986	3	1.2	3	10	1.64	2.11	.975	1.5	1.29	2.24	1.5-2
Eye of male	40	.715	.869	.650		10	.428	.537	.325		.66		
Eye of female	31	.607	.685	.571		6	.321	.373	.276				
Egg.....	25	.328	.373	.308		4	.189	.195	.162				
Length of ovisac.....	45	6.17	8	4	8	6	3.71	5	2	4-5	6.2		4- 5
Caudal appendage of male + setæ.....	34	1.88	2.27	1.46		10	1.92	2.6	1.62		1.96	1.62	
Caudal appendage of male	35	1.13	1.46	.812	1	10	1.32	1.62	.975	1	.96	.86	1-1.5
Caudal appendage of female + setæ	6	1.80	1.99	1.19		6	1.95	2.27	1.42				
Caudal appendage of female.....	10	1.143	1.4	.65		6	1.115	1.46	.853	2			

¹ Verrill originally thought these distinct species; his measurements are given in these columns.

² Sars places the maximum limit at 23 mm. Measurements are all in millimeters.

situations. This material was carefully measured and compared with the material of *B. coloradensis* and also with the measurements and descriptions of *B. paludosa* as given by Verrill (1870), Packard (1883) and Sars (1896). The results of these measurements are given in the above table:

It is clear from the measurements that *B. coloradensis* and *B.*

paludosa are of about the same size, while *B. Lindahli* is somewhat smaller. The body of *B. coloradensis* is not only larger but more robust than that of *B. Lindahli*. The latter is much more "fairy-like" in appearance, and specimens in formalin are perfectly white or transparent. The color of *B. coloradensis* is much more variable. It has not changed in formalin and varies from creamy white to salmon. In the material collected July 29, 1904, were 26 males and 56 females; the males were light and the females were salmon without a single exception. But of the 14 males and 26 females collected July 12, 1904, there were several exceptions to this color distinction.

Perhaps the most noticeable difference between *B. Lindahli* and *B. coloradensis* is in the size and shape of the eye. (Pl. I.; 13, 14, 15, 16). Packard (1883: 338) describes the eyes of *B. coloradensis* as "rather larger" than those of *B. paludosa*, and the eyes of *B. Lindahli* as "rather large." A reference to the table shows that the eyes of *B. coloradensis* are much larger than those of *B. Lindahli*, the ratio derived from the average measurements being for the males 1.67 to 1 and for the females 1.89 to 1. It must be understood that, since the writer has only 6 females of *B. Lindahli* the ratio for these may not express as nearly the average as does the ratio for the males. Verrill (1870: 245) gives 0.66 mm. as the measurement of the eye of the male of *B. paludosa*. This almost equals the smallest measurements of *B. coloradensis*, but is considerably larger than the largest measurements of *B. Lindahli*. In *B. Lindahli* the ocular globe is developed but slightly better on the anterior side than on the posterior side. In *B. coloradensis*, however, the anterior side is developed much more than the posterior, or it may be said that the eye is bent forward abruptly at the place of union between the ocular globe and the peduncle. When viewed from above, these eyes are very distinct from those of *B. Lindahli* and can be distinguished at a glance. Although the eyes of the female are somewhat smaller in each case than those of the males, they are of the same form. Judging from Sars' description (1896: 44; Pl. VI., Fig. 9; Pl. VII., Figs. 1 and 2) the eyes of *B. paludosa* are more like those of *B. Lindahli* than like those of *B. coloradensis*.

The second antennæ, or claspers, of the males differ rather markedly in these three species. *B. paludosa* is distinct because of the toothed inner margin of the first division, and of the gradually tapering second division which ends in a bluntly rounded point. In both *B. coloradensis* and *B. Lindahli* the distal ends of the second antennæ are turned in rather abruptly (Pl. X., 7, 8; Pl. XI., 23, 24). *B. Lindahli* has, as a rule, shorter claspers than *B. coloradensis*. But this cannot always be depended upon, for the measurements show that it is not an uncommon thing to find *B. Lindahli* with second antennæ longer than those of *B. coloradensis*, even though the body length of the latter exceeds by several millimeters that of the former. There is, however, a considerable difference in the average length of the claspers of these two species. The average measurement of 40 specimens of *B. coloradensis* is 5.33 mm., varying from 3.5 mm. to 9 mm.; while the average of 10 specimens of *B. Lindahli* is 3.87 mm., varying from 2.26 mm. to 5 mm.; the ratio between the averages of *B. coloradensis* and of *B. Lindahli* is 1.37 to 1. Only one individual of *B. coloradensis* had claspers 9 mm. long, and this is probably exceptional, since the next longest measured only 7.2 mm.

The basal division of the claspers of *B. Lindahli* is of about the same thickness as that of *B. coloradensis*. It is somewhat shorter, however, the ratio being 1. to 1.49. The outer margin of the first division of the clasper of *B. Lindahli* has a number of very delicate sensory hairs. Near the base on the inner side there is a raised portion bearing teeth (Pl. X., 7*ta*). Teeth are totally lacking as we approach the distal end. This division of the claspers of *B. coloradensis* is notably different. The toothed area is about half way between the ends on the inner side (Pl. X., 8*ta*). Near the base there is a prominent tubercle of considerable length. This tubercle is characteristic of full grown males. It is not plainly seen unless the clasper is bent forward, when it stands out prominently on the inner side. It is often a third as long as the width of the basal division (Pl. X., 8*t*; Pl. XI., 23).

The second division of the clasper is about the same thickness in the two species. The length is somewhat less in *B. Lindahli* than in *B. coloradensis*. In each species the inturned portion varies greatly in outline, depending on the point of view (Pl. X., 7,

8, 9, 10, 11, 12; Pl. XI., 23, 24). Viewed from the front or back, the tips of *B. Lindahli* are much more gradually pointed than those of *B. coloradensis* (Pl. X., 7, 9, 11), but when viewed from above or below, the reverse is true. This is due to the fact that the already flattened second division of *B. Lindahli* is still more flattened on the outer or lower side as the inturned tip is approached, and this gives the lower part a truncate or slightly convex appearance (Pl. X., 7, 10, 11; Pl. XI., 24). In *B. coloradensis*, instead of the lower part of the tips being flattened, there is developed a prominent ridge and this, together with a less prominent ridge on the upper side, gives the tip a very blunt appearance when viewed from the front (Pl. X., 8, 12; Pl. XI., 23). The tip in *B. coloradensis* is flattened on the anterior and posterior sides, while the tip in *B. Lindahli* is flattened dorso-ventrally.

In *B. paludosa* the second division of the clasper tapers rather gradually to the blunt end, which is not inturned as in the other two species under consideration. The ratio between the length of the second joint and the first is for *B. coloradensis*, 1 to 1.68; for *B. Lindahli* 1 to 1.36; and for *B. paludosa* 1 to 1.28.

In young specimens of *B. coloradensis* the tubercle of the basal joint is often absent. It is also not uncommon to find such specimens with the second division ending rather bluntly, and not inturned. When in this condition, the second division resembles the corresponding division of *B. paludosa*.

The eggs of *B. paludosa* and *B. Lindahli* are of the same size (Packard, 1883 : 340). Those of *B. coloradensis* are much larger, the ratio being 1.74 to 1.

The average length of the ovisac of *B. coloradensis* was 6.17 mm., varying from 4 mm. to 8 mm.; that of *B. Lindahli* was 3.71 mm., varying from 2 mm. to 5 mm., the ratio between the two species being 1.66 to 1. The ovisac of *B. Lindahli* is thicker in proportion to its length, and often contains 50 or more eggs arranged in from three to five rows, while the ovisac of *B. coloradensis* seldom contains as many as 30 eggs, and these generally arranged in from one to three rows (Pl. XI., 17, 18).

The caudal appendages of *B. Lindahli* are much longer in proportion to their breadth than those of *B. coloradensis* (Pl. XI., 19,

20, 21, 22). They are practically identical with the illustration of the caudal appendages of *B. paludosa* as given by Sars (1896 Pl. VI., 10).

Packard's original description of *B. Lindahli* (1883: 339) is the only one known to the writer. For this description Packard had only the collection made at Wallace, Kansas, by Professor Lindahl. This collection contained 10 females and only 1 male. To judge from the description this male was an exceptionally small one and evidently not a typical specimen. It therefore seems best to give the more important specific characters of the male of this species:

Body long and slender, from 8 mm. to 17.5 mm. in length, less robust than that of *B. coloradensis*; second antennæ long and powerful, reaching to the base of the fifth or sixth foot, 2.2 mm. to 5 mm. in length, somewhat shorter than those of *B. coloradensis*; first division 1.2 mm. to 2.9 mm. in length, thick and provided on the outer margin with delicate sensory hairs, an elevated toothed area near the base on the inner side; shorter than the first division of *B. coloradensis*, of about the same thickness but lacking the prominent tubercle at the base; second division curved, shorter than the first, ratio to the first 1 to 1.36, the outer surface flattened and meeting the arched inner surface in two prominent angles. When viewed from the front or back, less than half as thick as the basal division. The flattened outer surface bends forward to the prominently inturned tip, which is more flattened below than above. This dorso-ventral flattening of the inturned portion causes it to appear very blunt when viewed from above or below, but to appear rather gradually pointed when viewed from the front or back. Eyes rather large, 0.325 mm. to 0.537 mm. in diameter, the ocular globe but slightly better developed anteriorly than posteriorly, and not much larger than the peduncle: much smaller than the eye of *B. coloradensis*—ratio 1 to 1.67; caudal appendages narrow-lanceolate, length plus setæ 1.62 mm. to 2.6 mm.; length of appendage 0.975 mm. to 1.62 mm.; longer in proportion to the breadth than those of *B. coloradensis*.

This species can be distinguished easily from *B. coloradensis* by the smaller eye and egg, by the difference in the shape of the

eye, and by the greater number of eggs in the ovisac; by the absence of the basal tubercle on the second antennæ of the male, by the difference in the tips of the second antennæ, and by the longer and more slender caudal appendages.

It can be distinguished from *B. paludosa* by the absence of the teeth on the inner margin of the basal division, and by the inturned distal end of the second division of the second antenna.

Of the 82 females of *B. coloradensis* only two had both caudal appendages perfect, and only 6 of the 164 single caudal appendages were perfect. Forty males of *B. coloradensis* had only 11 imperfect appendages. No imperfect appendages were found on *B. Lindahli*.

A careful examination of the larvæ of *B. coloradensis* showed only perfect caudal appendages. From this it seems practically certain that the appendages of the adults were originally perfect. The tips of the appendages were first to disappear, and the appendages were then gradually shortened until only a small portion, or nothing at all was left (Pl. XII., 25 to 33). In all but a comparatively few, this change seemed to be a normal process. There was no sign of outward injury, but all the appearance of a gradual removal or absorption of the living substance. This appeared to be the same process by which the large swimming second antennæ of the larvæ are reduced to the much smaller and more simple second antennæ of the adult female.

A number of the appendages of both males and females showed parts of the appendage blackened by disease (Pl. XII., 29, 34 to 38), but this could not be mistaken for the other change. This blackening appeared in only a comparatively few of the appendages, and the number of males and females thus affected was about equal.

The caudal appendages of *B. coloradensis* first make their appearance as little knobs at the end of the common unsegmented body mass (Pl. X., 1, 2). The point of the knob is pushed out to form a stout, short, curved projection which will ultimately develop into the end or one of the end bristles of the mature appendage. By the time twelve body segments have developed, another small point is formed outside of the first bristle (Pl. X., 3). When all the abdominal segments can be seen, two more

points have developed, one on either side (Pl. X., 4). These bristles now develop alternately until all are formed; the constriction between the appendage and the abdomen does not appear until the appendage is almost mature (Pl. X., 5, 6).

B. coloradensis was collected in Dead Lake, a small body of water in the Pike's Peak region. This lake has already been described in some detail by Ward (1904: 131, 135, Pl. XXIX., XXIV., XXV). Without visible outlet or inlet, it lies on the divide between Ruxton Creek and Beaver Creek at an altitude of about 3,350 m. (11,000 feet U. S. Topographic Map). On the southeast side is the ridge leading to the summit of Bald Mountain. This ridge is covered with a dense coniferous forest, shading the lake during the morning. The lake measures about 100 m. by 75 m. and does not exceed 2 m. in depth. The forest barely touches the southeast shore. The remainder of the shore is a mountain meadow, with a few shrubs here and there, and numerous large boulders lying in and about the lake. The bottom of the lake is of blue clay, probably derived from the decomposition of the granite, which is the only rock of this region. It has the appearance of an old lake, one about to disappear (Ward, 1904: 132). There is very little change of level, and the lake is not known to have been dry. For the last 14 years during which time the writer has repeatedly visited this place, conditions have not changed in any marked degree. During the summer of 1904 a sawmill and air pump were operated on the shore, without affecting the life in any marked degree. The water is clear, pure and very slightly alkaline. On July 12, 1904, one drop of dilute H_2SO_4 in which 1 cc. = 50.954 mg., was sufficient to neutralize 100 cc. of lake water, with methyl orange used as an indicator.

The earliest collections were made on May 20, 1904, the day when the ice broke, and while the southeast side was still partially covered with ice. The temperature of the water was $4^{\circ}.7$ C. in the warmest places, and varied to almost 0° C. in the coldest. Many larvæ had appeared, among which were those of *B. coloradensis*. These varied in stages of development from those in which only the antennæ, mandibular legs, and unsegmented body could be seen, to those in which all the segments had been formed.

On June, 4, the ice had all disappeared except at the south-east edge, and the warmest temperature was $6^{\circ}.2$ C. In this collection the larvæ were well developed, but none of those taken had transformed the swimming antennæ. They were larvæ of the last stage (Sars, 1896 : 55, Pl. VI., 5, 6). At the time of the next collection, June 17, the water temperature was $12^{\circ}.2$ C. and none of these forms were taken in the Birge net. While the mature animal was never captured in this way the larvæ of the last stage were easily taken in the net, so that, these forms were probably mature at this time.

The mature animals were extremely abundant July 12, with a surface temperature of $13^{\circ}.6$ C., and were equally abundant July 29, when the temperature was the same. At this time there was only $0^{\circ}.2$ C. difference between the surface and bottom temperatures. On August 12, with a surface temperature of $15^{\circ}.6$ C. the *Branchinecta* had disappeared. After a diligent search, one was seen, but although the search was continued no others were found. The bottom collections made at this time were filled with decomposing fragments of *Branchinecta*.

Ward (1904 : 139) recorded this form for July 13, 1903, when the surface temperature was $14^{\circ}.4$ C., and they were collected by the writer on August 13 of the same year.

From the above, it is clear that segmentation and most of the embryonic development must have taken place under the ice. the writer has no records of the temperature of the water before the ice broke, but this temperature according to Zchokke (1900 : 45) probably did not exceed $2^{\circ}.2$ C. By the time the temperature had risen to $6^{\circ}.2$ C. the larvæ were in the last stage of their development, and at $13^{\circ}.6$ C. the animals had become fully mature. They had disappeared when the temperature had risen to $15^{\circ}.6$ C. This was the warmest temperature recorded for this Lake. The mature forms were never abundant in the open water. They collected about the rocks and near the shore where they could be seen in great numbers swimming on their backs.

On August 12, 1903, as well as on July 12 and 29, 1904, the setæ of the legs and caudal appendages bore numbers of a green alga *Characium ambiguum* Hern. On July 29, these algæ were so numerous that many of the *Branchinecta* could swim only

with slow labored movements, and this may have contributed to the sudden disappearance of the phyllopods.

This lake has no vertebrate fauna of any kind. The most common species besides the one here considered is *Diaptomus shoshone* Forbes (Ward, 1904 : 140) which is a very large form, of a pure deep red color, and very abundant. *Daphnia pulex* De Geer (Ward, 1904 : 149) and *Daphnia longispina* Müller are also quite abundant. The bottom fauna is especially rich in insect larvæ and Turbellaria. The flora is entirely algal, chiefly Conjugatæ, which are relatively abundant. The Schizophyceæ are well represented ; *Merismopedia glauca* Naeg., *Gomphosphæra aponica* Kuetz., *Anacystis pulverens* (Wood) Wolle, and a number of *Oscillatoria* and other filamentous forms were recorded.

The writer wishes to acknowledge his indebtedness to Dr. H. B. Ward, who suggested a study of the lakes in the Pike's Peak region and the comparison of *B. coloradensis* with *B. Lindahli*, who furnished the material of *B. Lindahli* collected by Professor Nelson, and who has given invaluable assistance in the preparation of these notes.

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EXPLANATION OF THE PLATES.

The figures are original drawings from material preserved in formalin. The outlines and some details were made with the assistance of the Abbé camera lucida, and the drawings were completed at the time from the same specimens.

PLATE X.

FIG. 1. Posterior end of the body of a larva of *C. coloradensis* showing the developing caudal appendages. $\times 119$. At this stage the body mass was unsegmented and the first and second antennæ and mandibular legs alone could be distinguished.

FIGS. 2-6. Developing caudal appendages of *B. coloradensis*.

FIG. 2. At the time when six body segments can be seen. $\times 119$.

FIG. 3. At the time when twelve body segments can be seen. $\times 119$.

FIG. 4. At the time when all abdominal segments can be distinguished. $\times 119$.

FIG. 5. Later stage. $\times 35$.

FIG. 6. A still later stage. $\times 35$.

FIG. 7. Male second antenna or clasper of *B. Lindahli*; *ta*, toothed area. $\times 20$.

FIG. 8. Male second antenna or clasper of *B. coloradensis*; *t*, tubercle; *ta*, toothed area. $\times 20$.

FIG. 9. Distal end of the male second antenna of *B. Lindahli* viewed from the front. $\times 35$.

FIG. 10. The same viewed from the outside. $\times 35$.

FIG. 11. The same viewed from the front and below. $\times 35$.

FIG. 12. Distal end of the male second antenna of *B. coloradensis* viewed from the outside. $\times 35$.

FIG. 13. Eye of the female of *B. Lindahli*, dorsal view; *a*, anterior side; *p*, posterior side. $\times 35$.

FIG. 14. Eye of the male of *B. Lindahli*, dorsal view; *a*, anterior side; *p*, posterior side. $\times 35$.

FIG. 15. Eye of the female of *B. coloradensis*, dorsal view; *a*, anterior side; *p*, posterior side. $\times 35$.

FIG. 16. Eye of the male of *B. coloradensis*, dorsal view; *a*, anterior side; *p*, posterior side. $\times 35$.

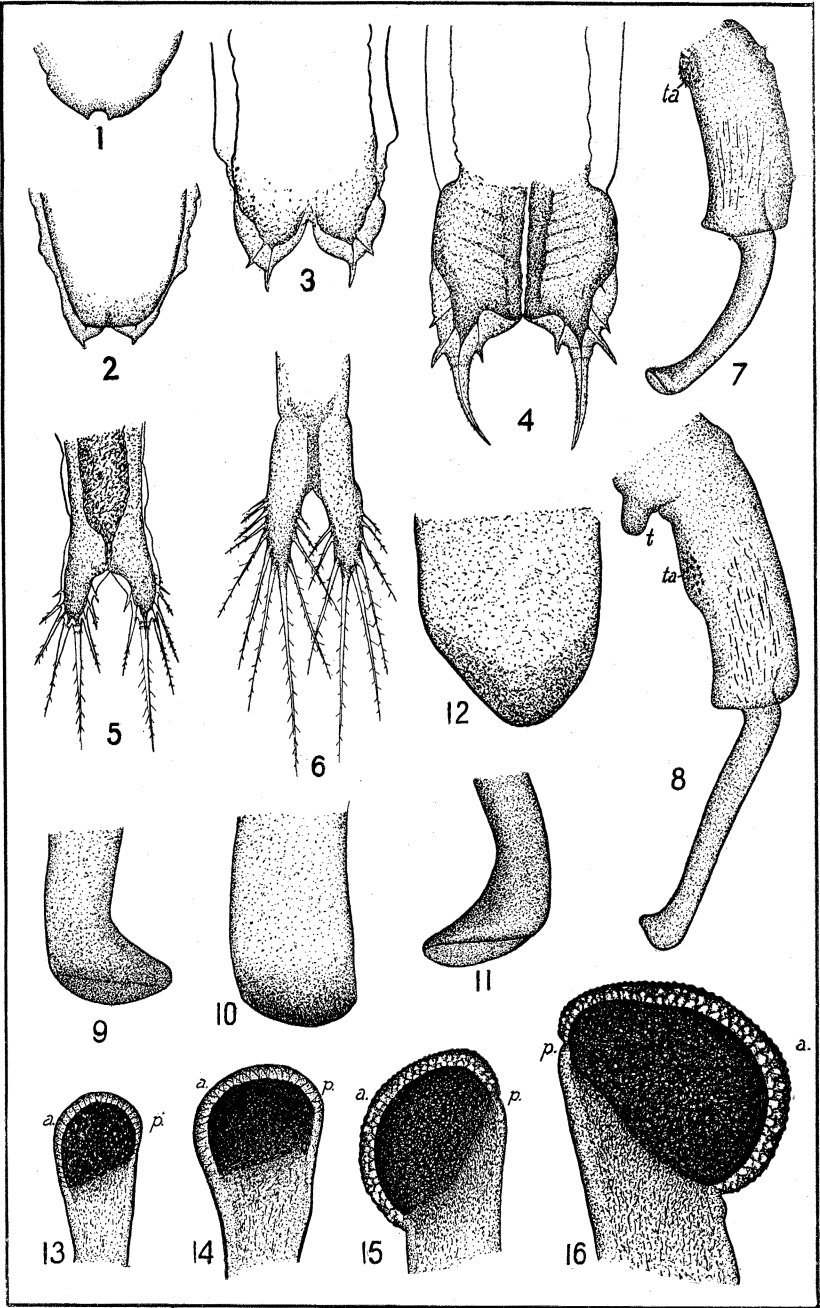


PLATE XI.

- FIG. 17. Ovisac of *B. Lindahli* with eggs. $\times 24$.
FIG. 18. Ovisac of *B. coloradensis* with eggs. $\times 24$.
FIG. 19. Caudal appendages of male of *B. coloradensis*. $\times 21$.
FIG. 20. Caudal appendages of female of *B. coloradensis*. $\times 21$.
FIG. 21. Caudal appendages of male of *B. Lindahli*. $\times 21$.
FIG. 22. Caudal appendages of female of *B. Lindahli*. $\times 21$.
FIG. 23. Head of male of *B. coloradensis*, front view. $\times 14$.
FIG. 24. Head of male of *B. Lindahli*, front view. $\times 14$.

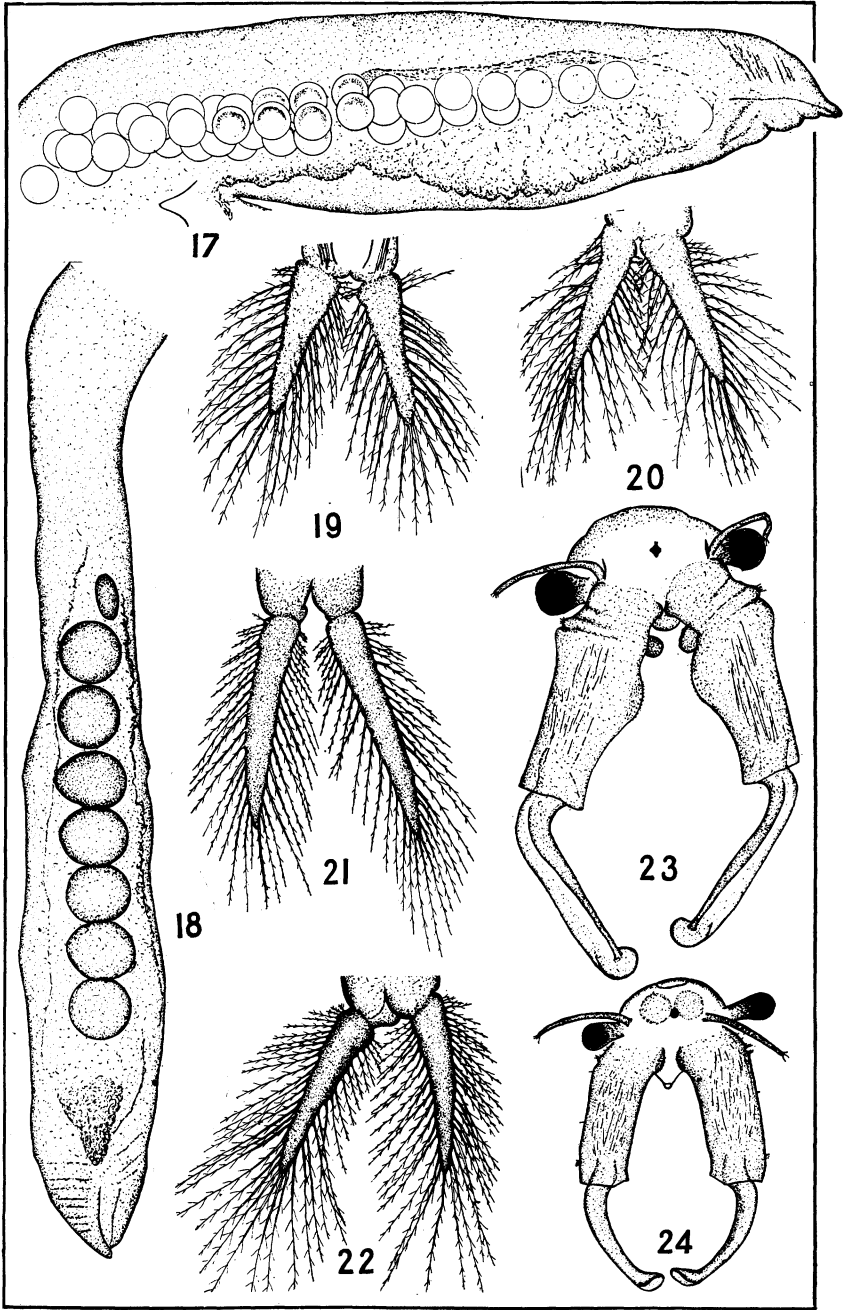


PLATE XII.

FIGS. 25-28, 30-33. Caudal appendages of females of *B. coloradensis* in various stages of absorption. $\times 25$.

FIGS. 29, 34-38. Diseased caudal appendages of females of *B. coloradensis*. $\times 25$.

FIG. 39. Branchial leg of the sixth pair of the male of *B. Lindahli*. $\times 14$.

